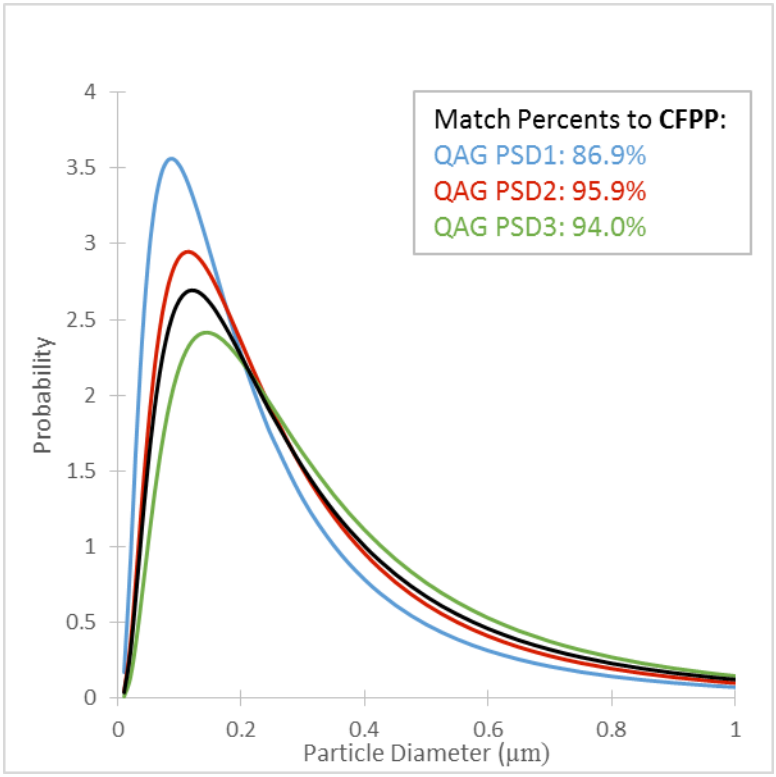
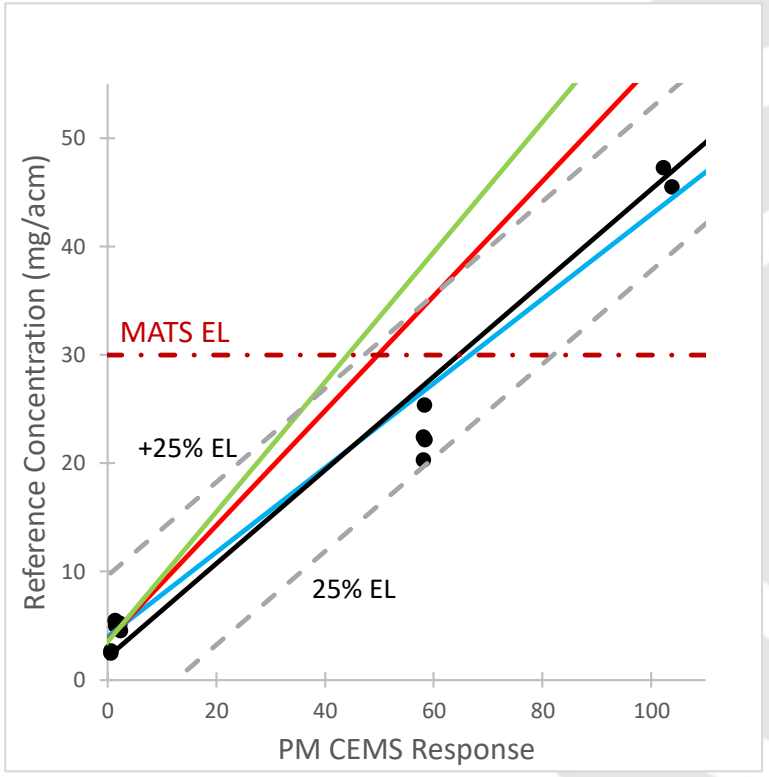
Quantitative Aerosol Generator (QAG) for PM CEMS Calibration





Troy Pittenger, Brian Edge & John Cooper
Cooper Environmental Services

Chuck Dene & Cassie Shaban - EPRI

International CEMS Conference
May 19th 2016

COOPER ENVIRONMENTAL

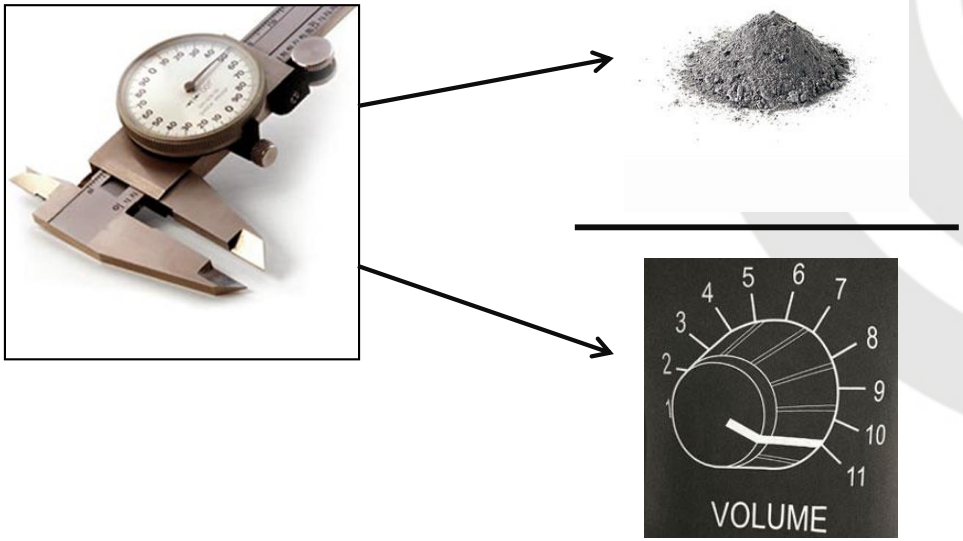
Overview

- Background & QA program
- Current application protocol
- Demonstrate instrumentation & protocol with field study data
  - Wet scrubbed power plant & extractive light scattering PM CEMS
- Conclusions

COOPER ENVIRONMENTAL

What is the QAG?

- An instrument that generates a traceable known concentration of aerosol and produces a known particle size distribution (PSD)
- Aerosol concentrations range from pg/m^3 to mg/m^3



COOPER ENVIRONMENTAL

Why?

- No traceable calibration standard exists to challenge/certify PM CEMS
- Current calibration method U.S. EPA Performance Specification 11 (PS-11) is difficult and costly
- PS-11 requires modification of power plant emissions to span analytical range
- If PM concentration falls outside the regulations, more reference method tests are required
- Want to develop an alternate calibration approach to PS-11

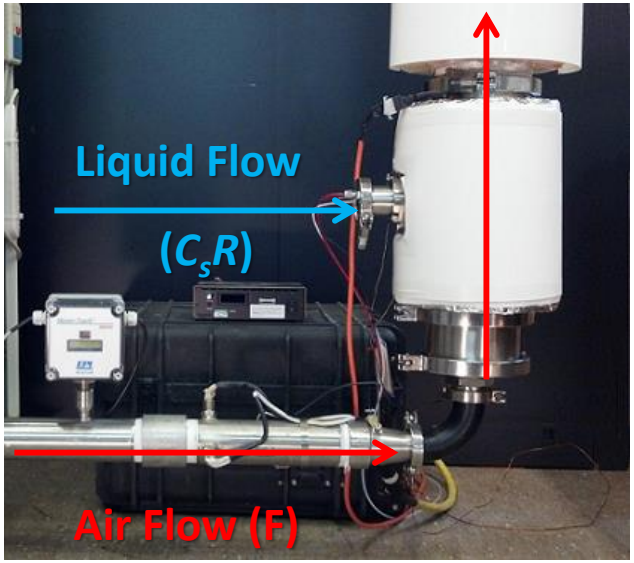
COOPER ENVIRONMENTAL

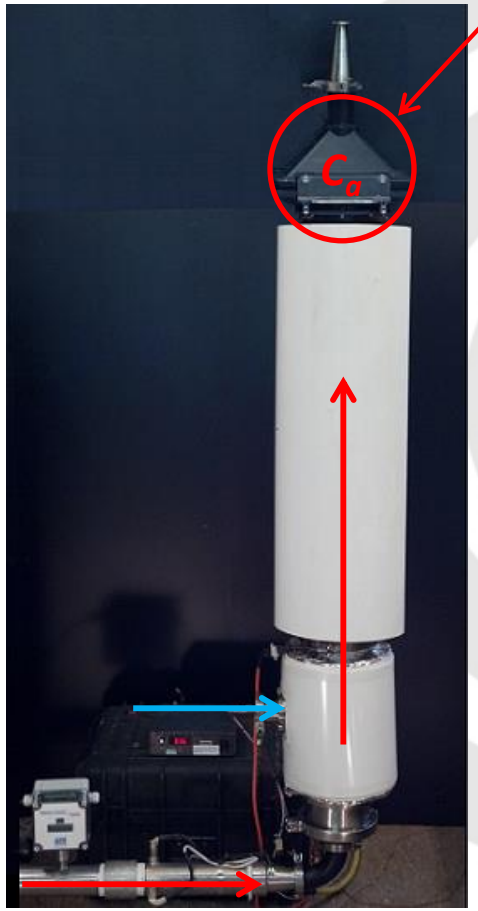
European Interest

- January 2015 meeting w/European PM CEMS vendors and PM regulator
  - PM CEMS vendors interested in providing their clients an easier method to calibrate their instrumentation
  - European regulator interested in QAG technology
    - Application: Very low PM emitting sources below manual reference method detection limits
- April 2015 follow up meeting with European PM CEMS vendors and PM regulator
  - European standard EN 13284-2 is under review
  - European regulators plan on integrating QAG technology into regulation for very low emitting sources (EN 13284-2, Section 7.3.3.3 & 7.3.3.4)
- October 2015 meetings with TUV and VGB working group
  - Europe has similar issues with achieving elevated PM concentrations as in the U.S.
  - Question: Why would industry perform QAG calibration if current option for low emitting sources is to perform no calibration on there instrumentation?

COOPER ENVIRONMENTAL

How it Works





$$C_a = \frac{C_s R}{F}$$

COOPER ENVIRONMENTAL

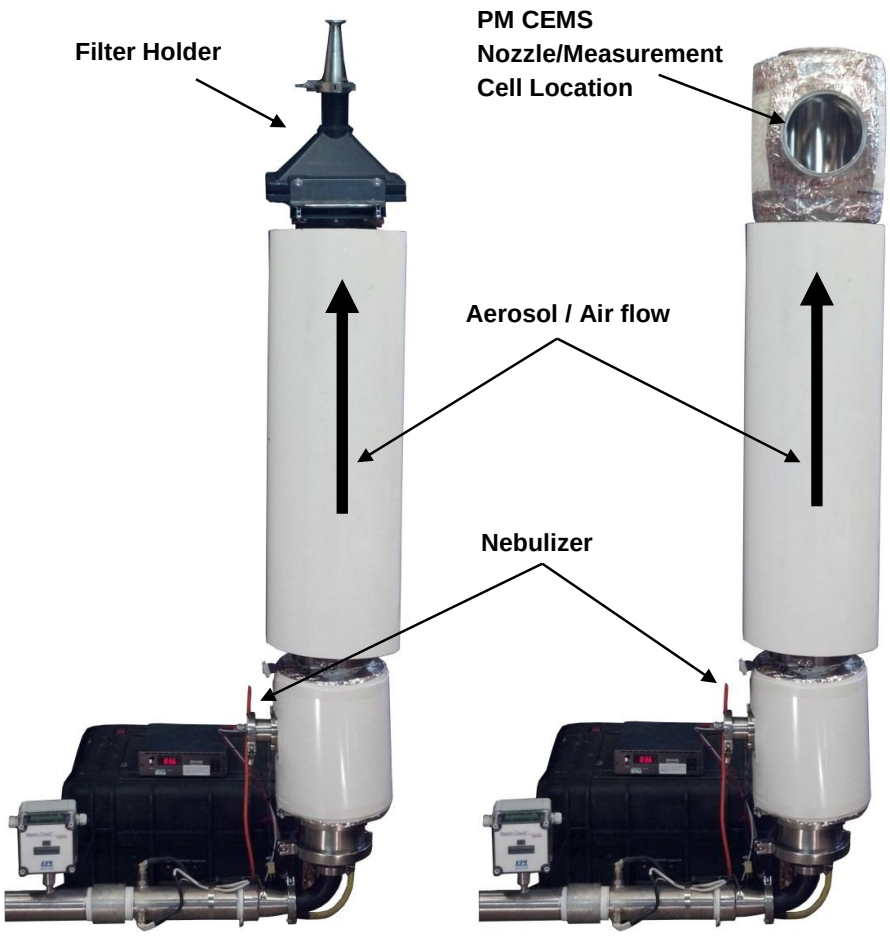
QAG QA/QC Program

- Check liquid flow measuring device daily w/NIST standards
- Certify air flow meter annually
- Certify air flow correction sensors annually
- Conduct total capture tests over the range of PM concentration used in the study
- Perform ongoing QA total capture tests following PM CEMS correlation

QAG QA/QC Program

Total capture aerosol concentration comparison

- C^G = Gravimetric determined conc.
- C^Q = QAG determined conc. (inputs)
- $\frac{C^G}{C^Q}$ X 100% = % recovery



COOPER ENVIRONMENTAL

QAG QA/QC Field Results

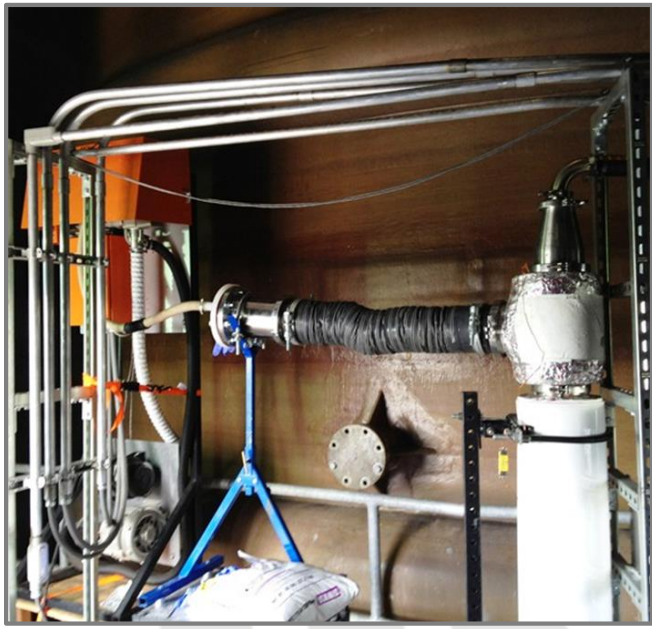
- Site #1 (Gen. 2 QAG) – 99% recovery over 14 days (n=33)
  - PM conc. 0 – 15 mg/dscm
- Site #2 (Gen. 2 QAG) – 88% recovery PM CEMS 1 & 2 (n=24)
  - PM conc. 0 – 75 mg/wscm
- Site #2 (Gen. 2 QAG) – 96% recovery PM CEMS 3 (n=16)
  - PM conc. 0 – 78 mg/wscm
- Site #3
  - PM
- Site #4
  - PM
- Site #5 (Gen. 3 QAG) – 99% recovery over 6 days (n=15)
  - PM conc. 0 – 7.5 mg/wscm
- Site #6 (Gen. 3 QAG) – 97% recovery over 4 days (n=19)
  - PM conc. 0 – 22 mg/acm
- Site #7 (Gen. 4 QAG) – 96% recovery over 4 days (n=24))
  - PM conc. 0 – 25 mg/wscm
- Site #8 (Gen. 4 QAG) – 98% recovery over 6 days (n=24)
  - PM conc. 0 – 33 mg/wscm

Overall Average Percent Recovery = 97% (n=225)

COOPER ENVIRONMENTAL

Example Experimental Setup

Extractive Beta Attenuation



Extractive Light Scatter

In-situ Light Scatter

COOPER ENVIRONMENTAL

Current QAG Application Protocol

1. **QA check both QAG and PM CEMS**
2. **Define final PM CEMS concentration correlation/calibration slope**
   a. Measure coal fired power plant (CFPP) PSD
   b. Generate three raw concentration correlations between the QAG and PM CEMS at three different particle size distributions (PSDs)
   c. Generate relationship between the QAG PSD central tendencies (CT) and the corresponding raw concentration correlation slopes
   d. Use relationship from Step 2c. and measured CFPP PSD CTs from Step 2a. to calculate the final PM CEMS concentration correlation slope
3. **Define final PM CEMS concentration correlation/calibration y-intercept**
   a. Perform three or more manual reference method (RM) tests under normal plant operations with PM CEMS installed and reporting concentrations
   b. Determine average manual reference method PM CEMS concentration response coordinate (x = PM CEMS response, Y = RM conc.)
   c. Position final PM CEMS concentration correlation/calibration slope to pass through the average coordinate from Step 3b by only changing the y-intercept

COOPER ENVIRONMENTAL

Field Study #8

Objective/Study Plan:

Evaluate applicability of using the QAG to calibrate a PM CEMS (Extractive Light Scattering):

- Measure CFPP PSD
- Match CFPP PSD with QAG aerosol
- Generate three PM CEMS correlations while closely matching CFPP and QAG PSDs

Site Background:

- Five units = 3,342 MW (gross plant total)
- Test unit (625MW) equipped with:
  - Selective catalytic reduction (SCR)
  - Electrostatic precipitator (ESP)
  - Wet flue gas desulfurization scrubber (WFGD)

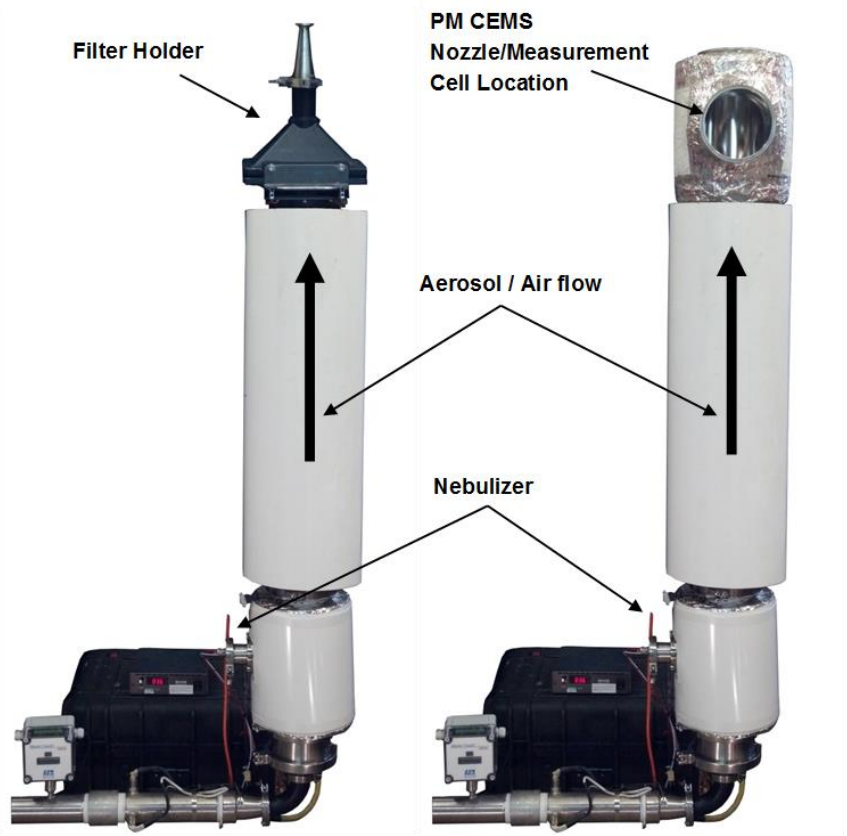
COOPER ENVIRONMENTAL

Current QAG Application Protocol

1. **QA check both QAG and PM CEMS**

QA Check Both QAG and PM CEMS

QAG QA Check



PM CEMS QA Check

1. QA check per manufacture's specifications
2. Completed initial 7-day drift testing

- Site #8 (Gen. 4 QAG) – 98% recovery over 6 days (n=24)
  - PM conc. 0 – 33 mg/wscm

COOPER ENVIRONMENTAL

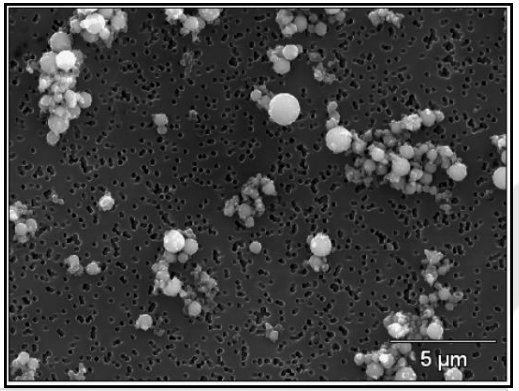
Current QAG Application Protocol

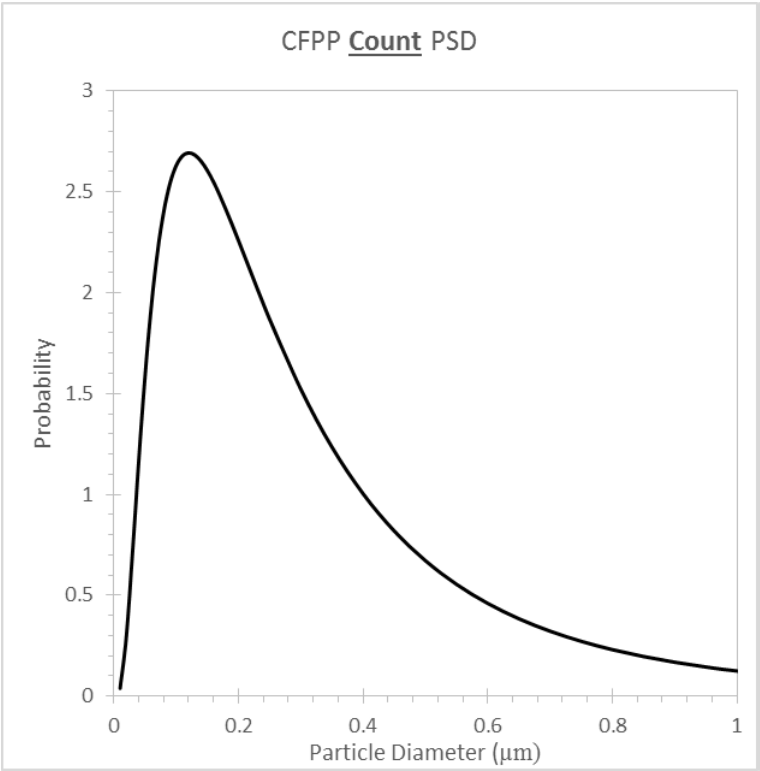
1. **QA check both QAG and PM CEMS**
2. **Define final PM CEMS concentration correlation/calibration slope**
   a. **<u>Measure coal fired power plant (CFPP) PSD</u>**

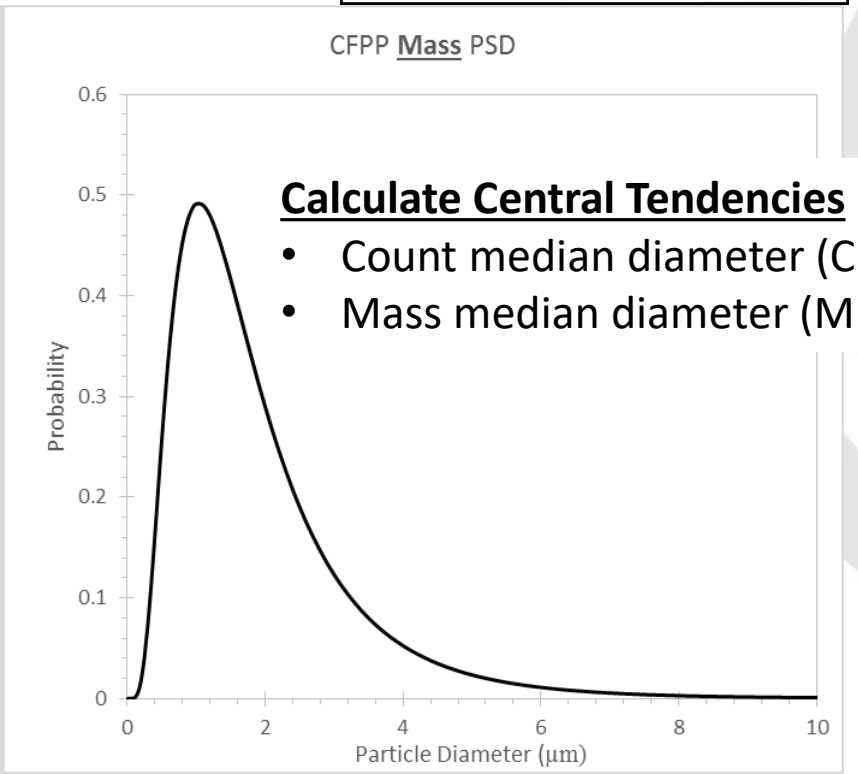
COOPER ENVIRONMENTAL

Measure CFPP PSD

Scanning Electron Microscopy (SEM)
Measured PSD







Calculate Central Tendencies

- Count median diameter (CMD) = 0.24µm
- Mass median diameter (MMD) = 1.58µm

COOPER ENVIRONMENTAL

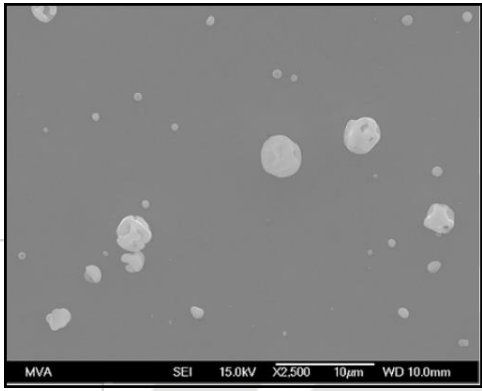
Current QAG Application Protocol

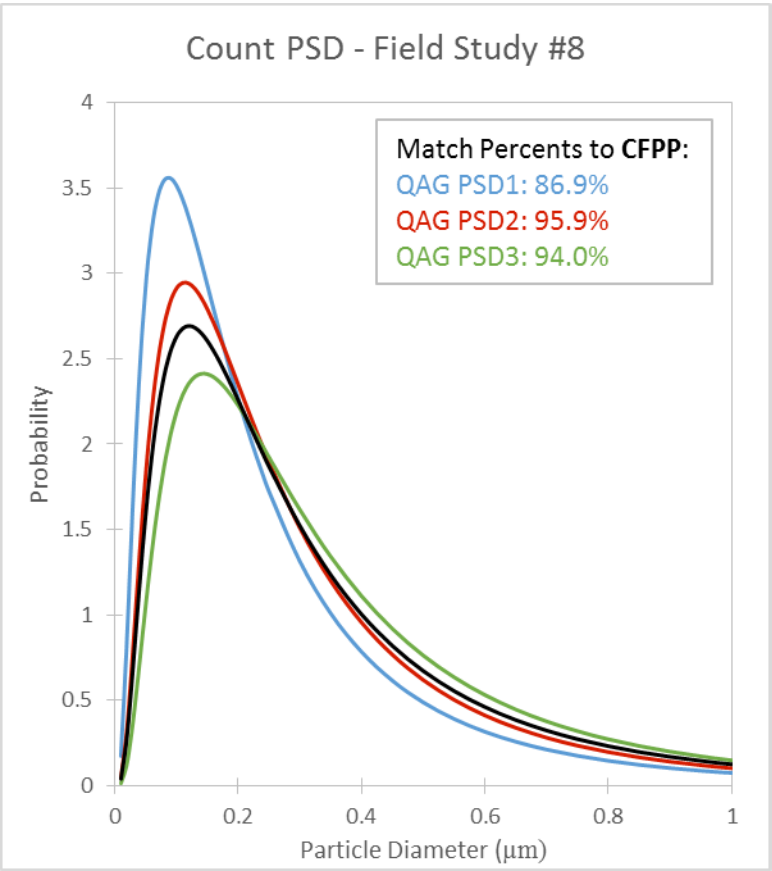
1. **QA check both QAG and PM CEMS**
2. **Define final PM CEMS concentration correlation/calibration slope**
   a. Measure coal fired power plant (CFPP) PSD
   b. <u>Generate three raw concentration correlations between the QAG (y-axis) and PM CEMS (x-axis) at three different PSDs</u>

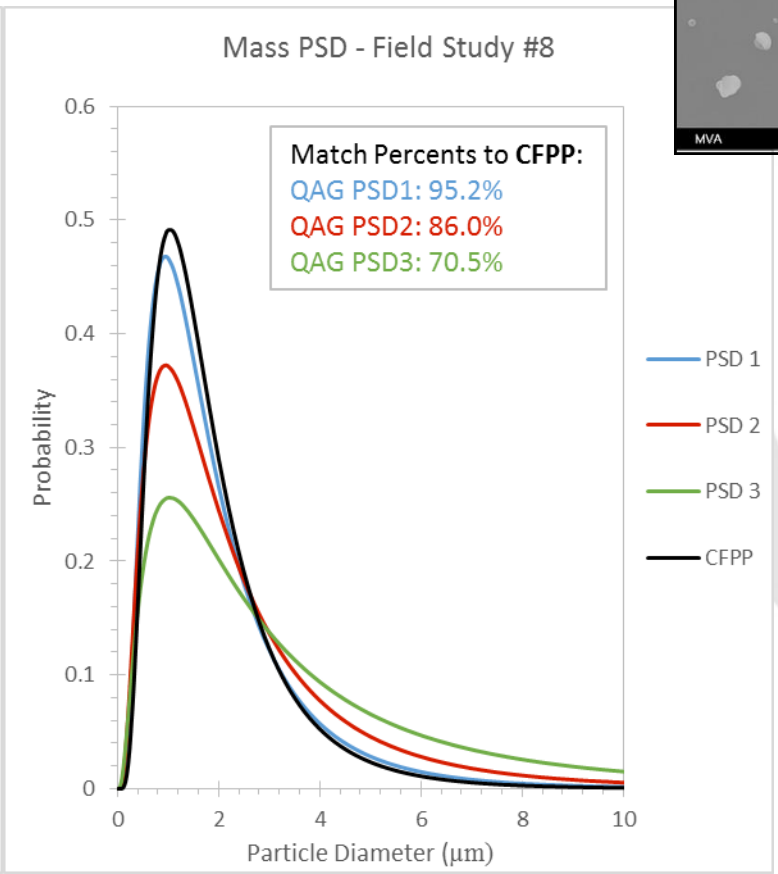
COOPER ENVIRONMENTAL

QAG Generate PSDs Compared to CFPP Measured PSD

Scanning Electron Microscopy (SEM) Measured PSD

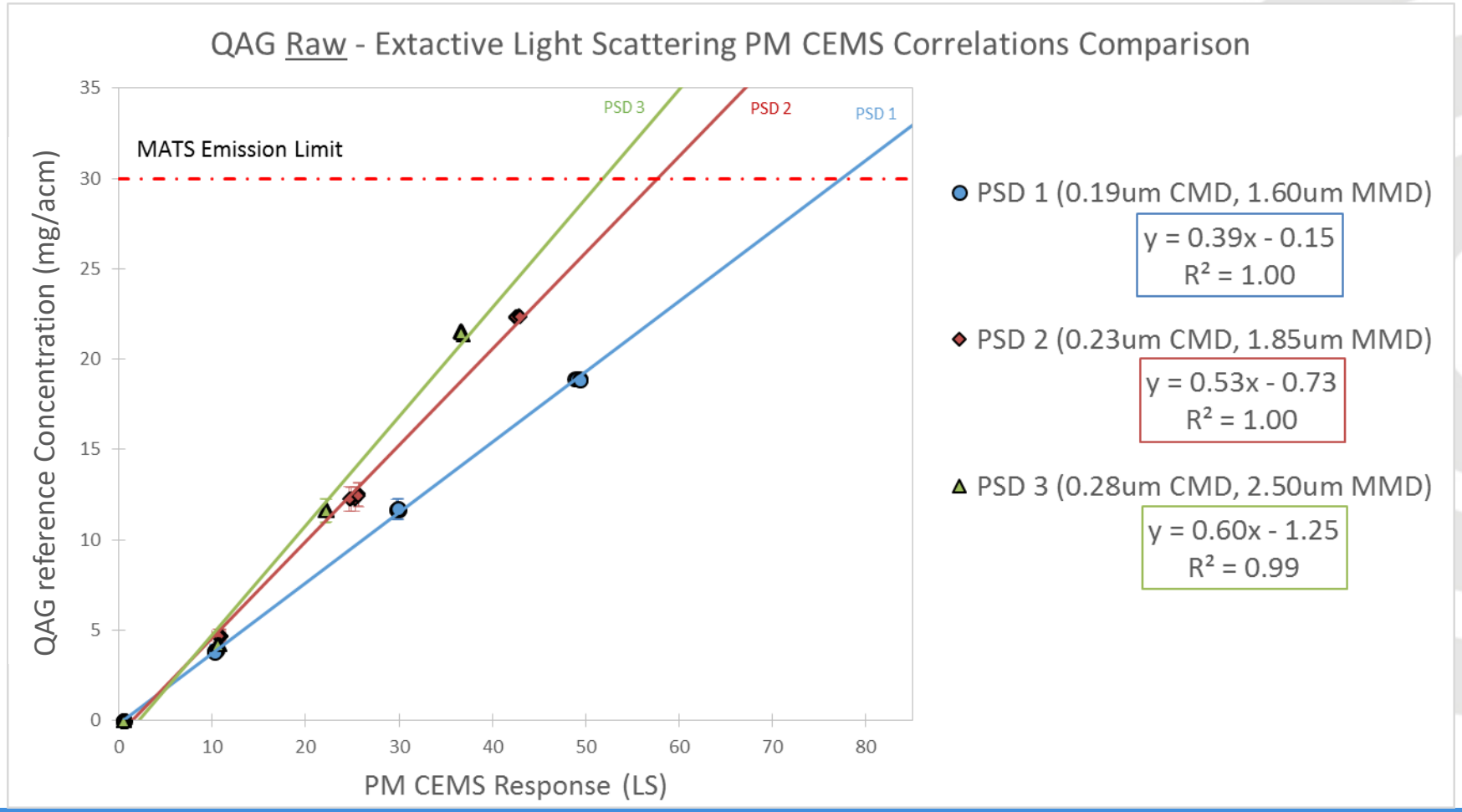






COOPER ENVIRONMENTAL

Generate Three Raw Concentration Correlations Between the QAG (y-axis) and PM CEMS (x-axis) at Three Different PSDs



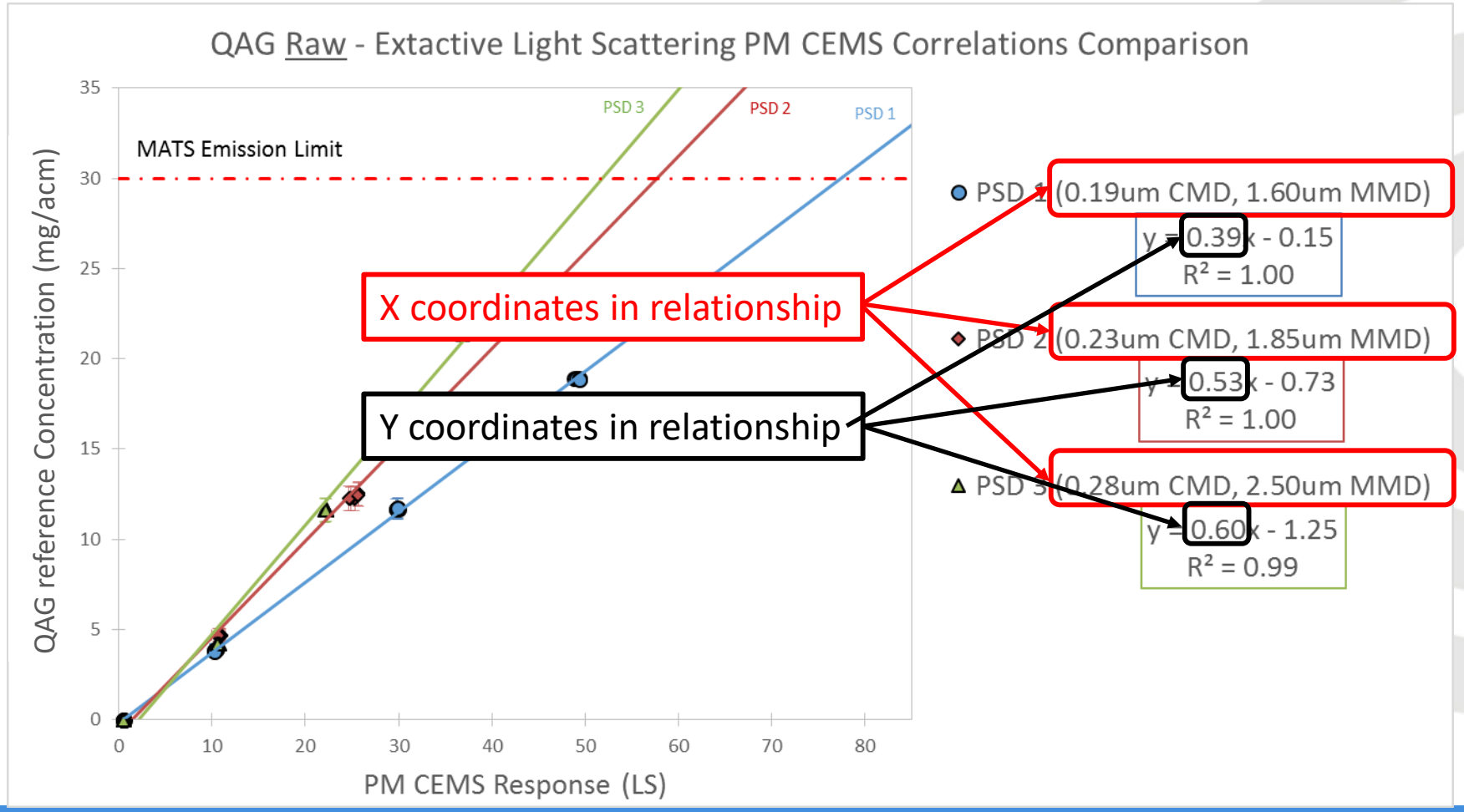
COOPER ENVIRONMENTAL

Current QAG Application Protocol

1. **QA check both QAG and PM CEMS**
2. **Define final PM CEMS concentration correlation/calibration slope**
   a. Measure coal fired power plant (CFPP) PSD
   b. Generate three raw concentration correlations between the QAG and PM CEMS at three different particle size distributions (PSDs)
   c. <u>Generate relationship between the QAG PSD central tendencies (CT) and the corresponding raw concentration correlation slopes</u>

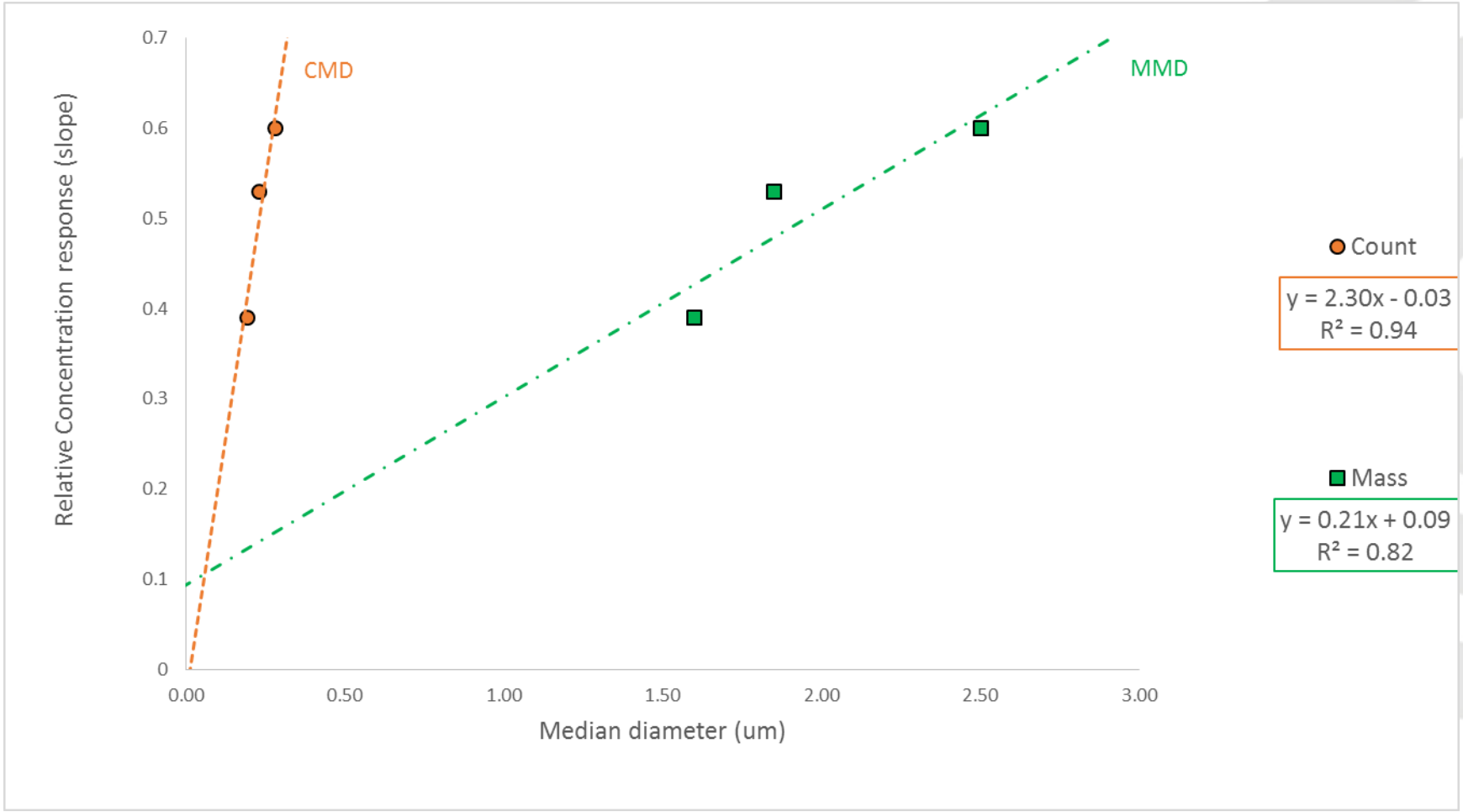
COOPER ENVIRONMENTAL

Generate Relationship Between the QAG PSD Central Tendencies (CT) and the Corresponding Raw Concentration Correlation Slopes



COOPER ENVIRONMENTAL

Generate Relationship Between the QAG PSD Central Tendencies (CT) and the Corresponding Raw Concentration Correlation Slopes



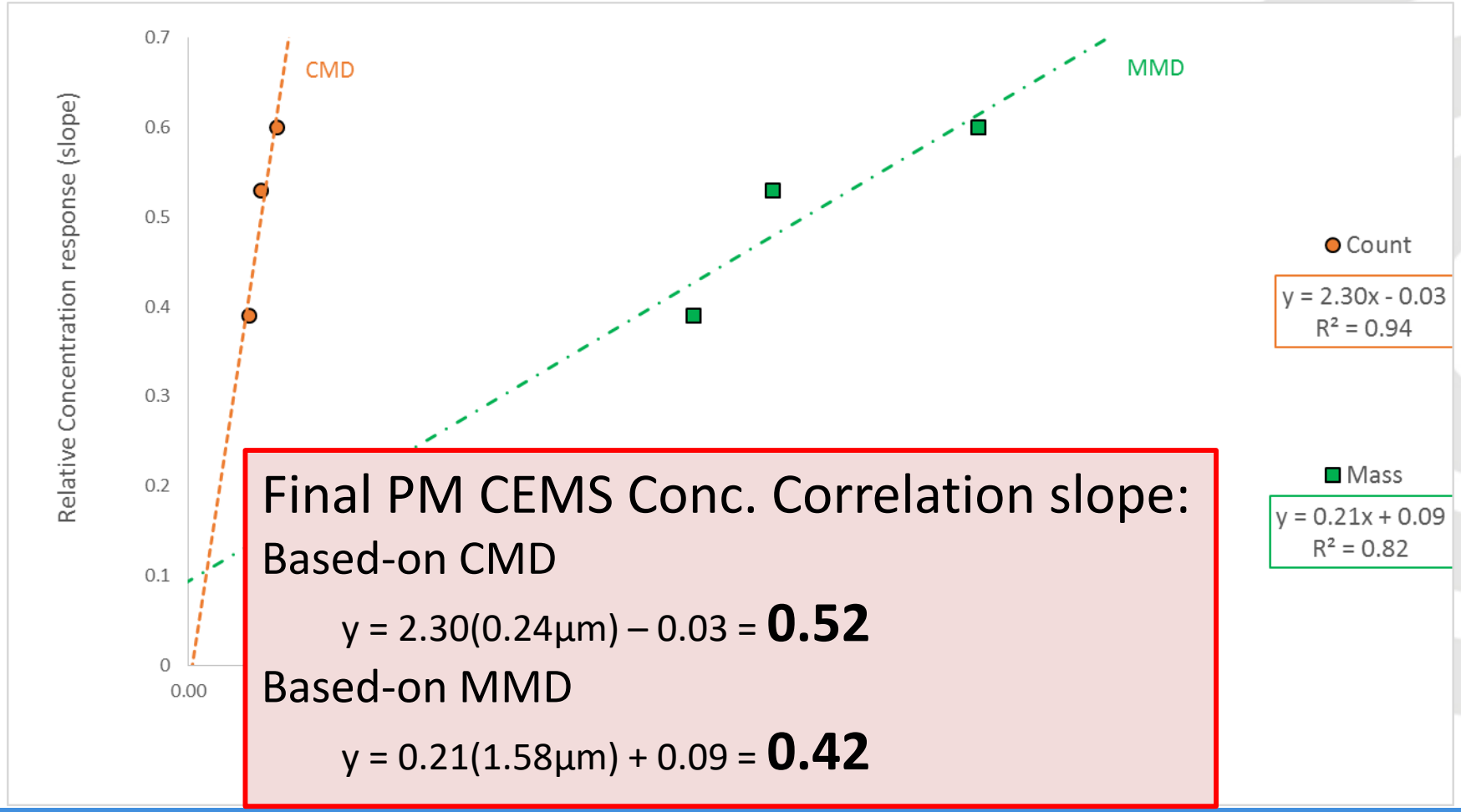
COOPER ENVIRONMENTAL

Current QAG Application Protocol

1. **QA check both QAG and PM CEMS**
2. **Define final PM CEMS concentration correlation/calibration slope**
   a. Measure coal fired power plant (CFPP) PSD
   b. Generate three raw concentration correlations between the QAG and PM CEMS at three different particle size distributions (PSDs)
   c. Generate relationship between the QAG PSD central tendencies (CT) and the corresponding raw concentration correlation slopes
   d. <u>Use relationship from Step 2c. and measured CFPP PSD CTs from Step 2a. to calculate the final PM CEMS concentration correlation slope</u>

COOPER ENVIRONMENTAL

Use Relationship from Step 2c. and Measured CFPP PSD CTs from Step 2a. to Calculate the Final PM CEMS Concentration Correlation Slope



Final PM CEMS Conc. Correlation slope:

Based-on CMD

$y = 2.30(0.24\mu m) - 0.03 =$ **0.52**

Based-on MMD

$y = 0.21(1.58\mu m) + 0.09 =$ **0.42**

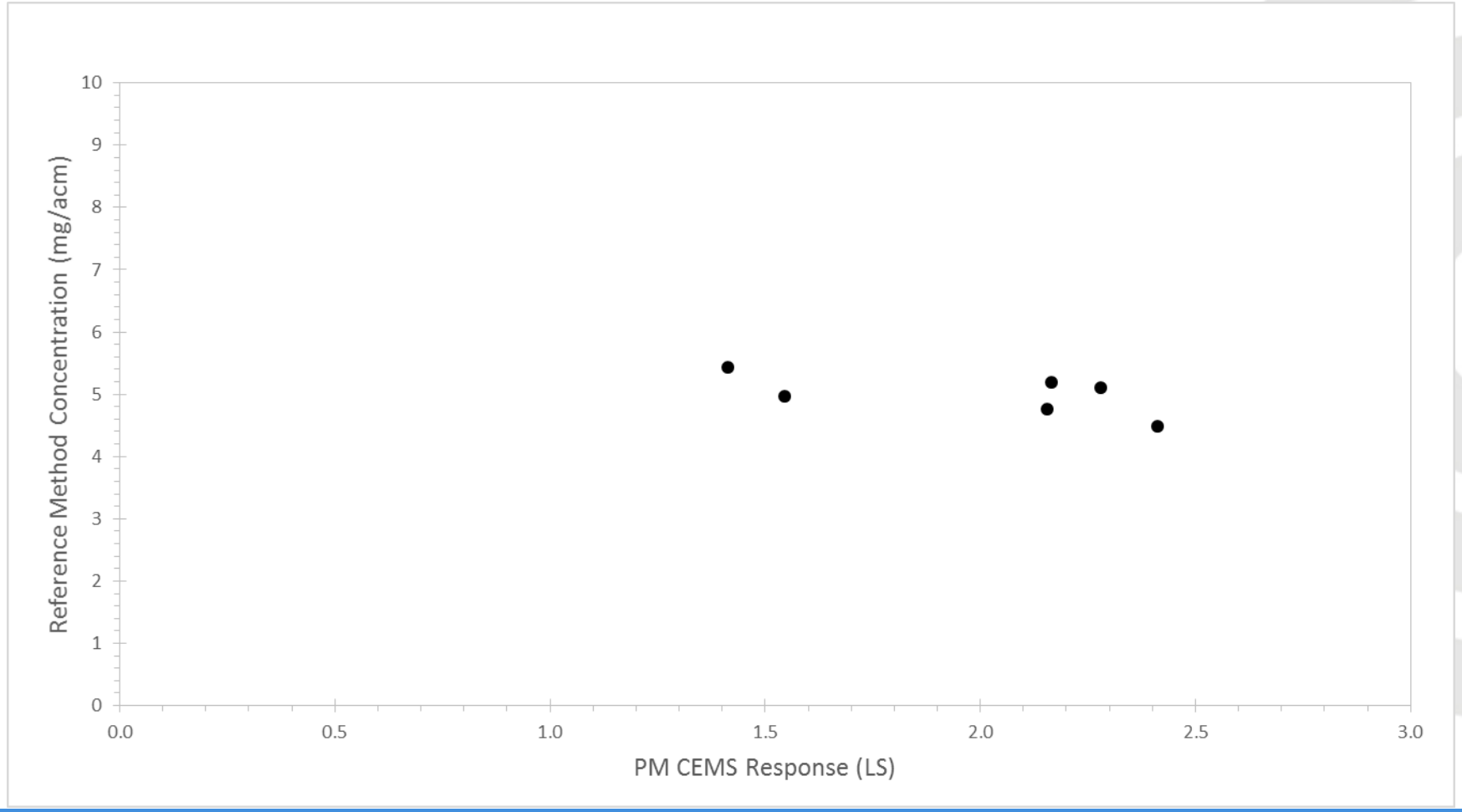
COOPER ENVIRONMENTAL

Current QAG Application Protocol

1. **QA check both QAG and PM CEMS**
2. **Define final PM CEMS concentration correlation/calibration slope**
   a. Measure coal fired power plant (CFPP) PSD
   b. Generate three raw concentration correlations between the QAG and PM CEMS at three different particle size distributions (PSDs)
   c. Generate relationship between the QAG PSD central tendencies (CT) and the corresponding raw concentration correlation slopes
   d. Use relationship from Step 2c. and measured CFPP PSD CTs from Step 2a. to calculate the final PM CEMS concentration correlation slope
3. **Define final PM CEMS concentration correlation/calibration y-intercept**
   a. **Perform three or more manual reference method (RM) tests under normal plant operations with PM CEMS installed and reporting concentrations**

COOPER ENVIRONMENTAL

Perform Three or more Manual Reference Method (RM) Tests Under Normal Plant Operations with PM CEMS Installed and Reporting Concentrations



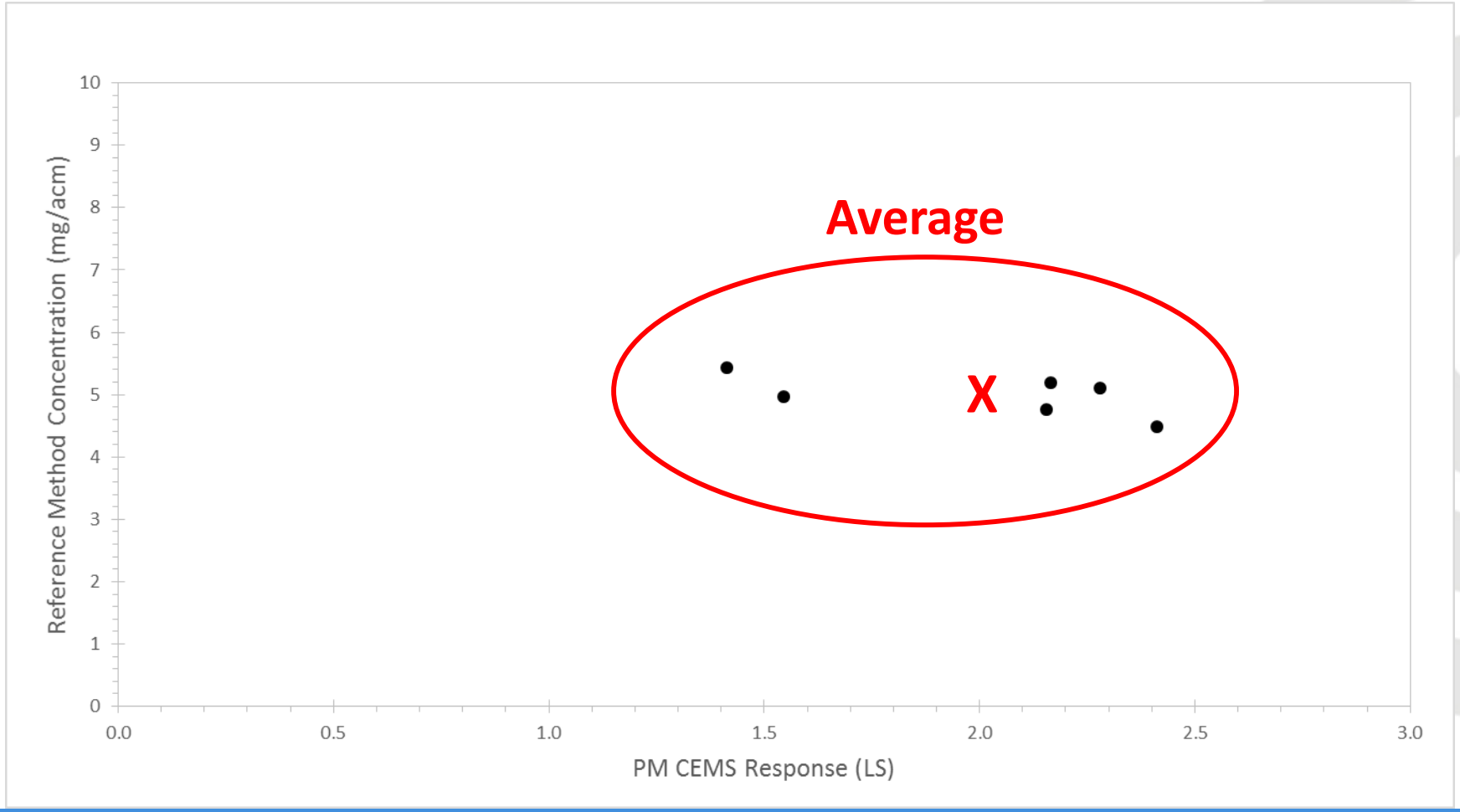
COOPER ENVIRONMENTAL

Current QAG Application Protocol

1. **QA check both QAG and PM CEMS**
2. **Define final PM CEMS concentration correlation/calibration slope**
   a. Measure coal fired power plant (CFPP) PSD
   b. Generate three raw concentration correlations between the QAG and PM CEMS at three different particle size distributions (PSDs)
   c. Generate relationship between the QAG PSD central tendencies (CT) and the corresponding raw concentration correlation slopes
   d. Use relationship from Step 2c. and measured CFPP PSD CTs from Step 2a. to calculate the final PM CEMS concentration correlation slope
3. **Define final PM CEMS concentration correlation/calibration y-intercept**
   a. Perform three or more manual reference method (RM) tests under normal plant operations with PM CEMS installed and reporting concentrations
   b. <u>Determine average manual reference method PM CEMS concentration response coordinate (x = PM CEMS response, Y = RM conc.)</u>

COOPER ENVIRONMENTAL

Determine average manual reference method PM CEMS concentration response coordinate (x = PM CEMS response, Y = RM conc.)



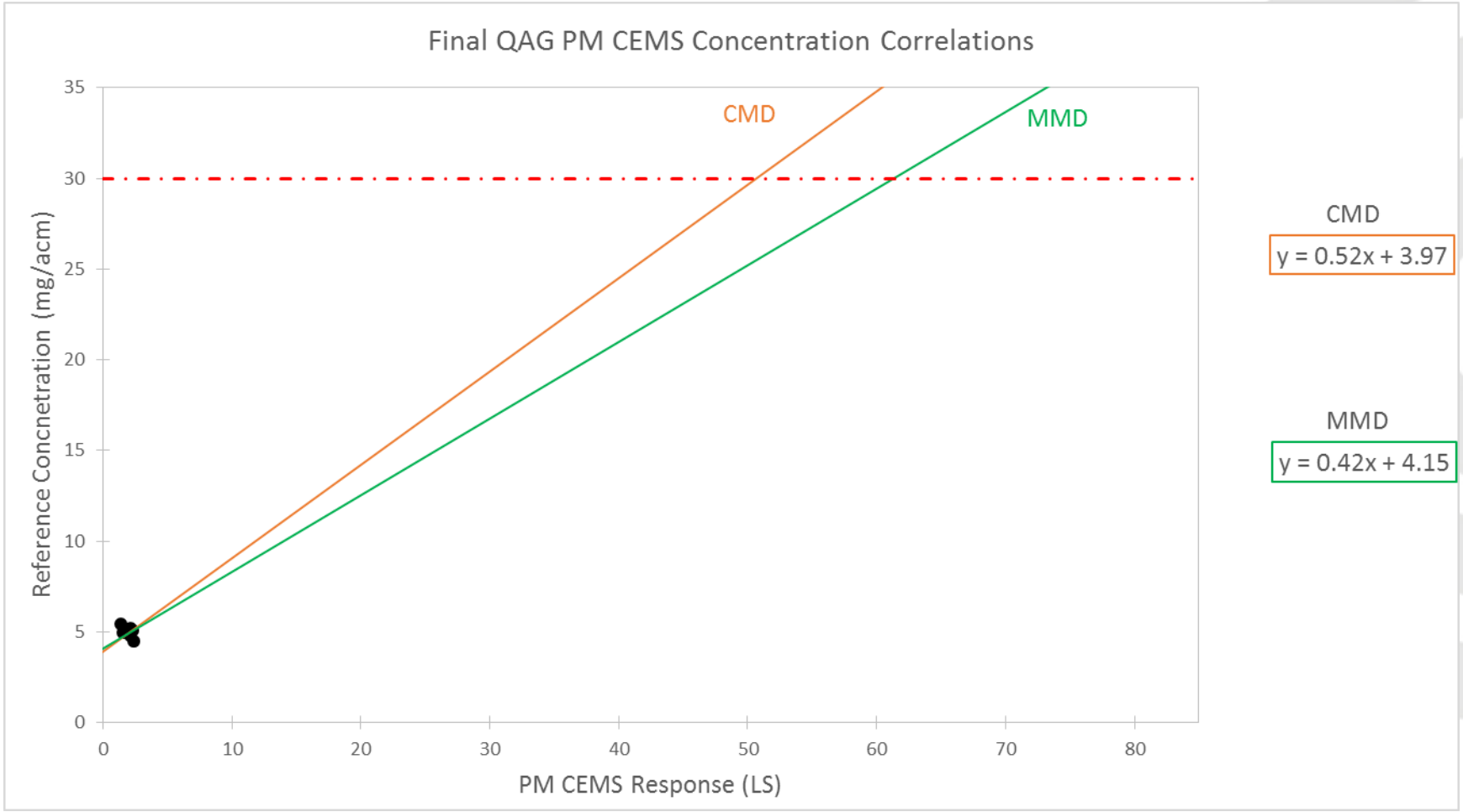
COOPER ENVIRONMENTAL

Current QAG Application Protocol

1. **QA check both QAG and PM CEMS**
2. **Define final PM CEMS concentration correlation/calibration slope**
   a. Measure coal fired power plant (CFPP) PSD
   b. Generate three raw concentration correlations between the QAG and PM CEMS at three different particle size distributions (PSDs)
   c. Generate relationship between the QAG PSD central tendencies (CT) and the corresponding raw concentration correlation slopes
   d. Use relationship from Step 2c. and measured CFPP PSD CTs from Step 2a. to calculate the final PM CEMS concentration correlation slope
3. **Define final PM CEMS concentration correlation/calibration y-intercept**
   a. Perform three or more manual reference method (RM) tests under normal plant operations with PM CEMS installed and reporting concentrations
   b. Determine average manual reference method PM CEMS concentration response coordinate (x = PM CEMS response, Y = RM conc.)
   c. **<u>Position final PM CEMS concentration correlation/calibration slope to pass through the average coordinate from Step 3b by only changing the y-intercept</u>**

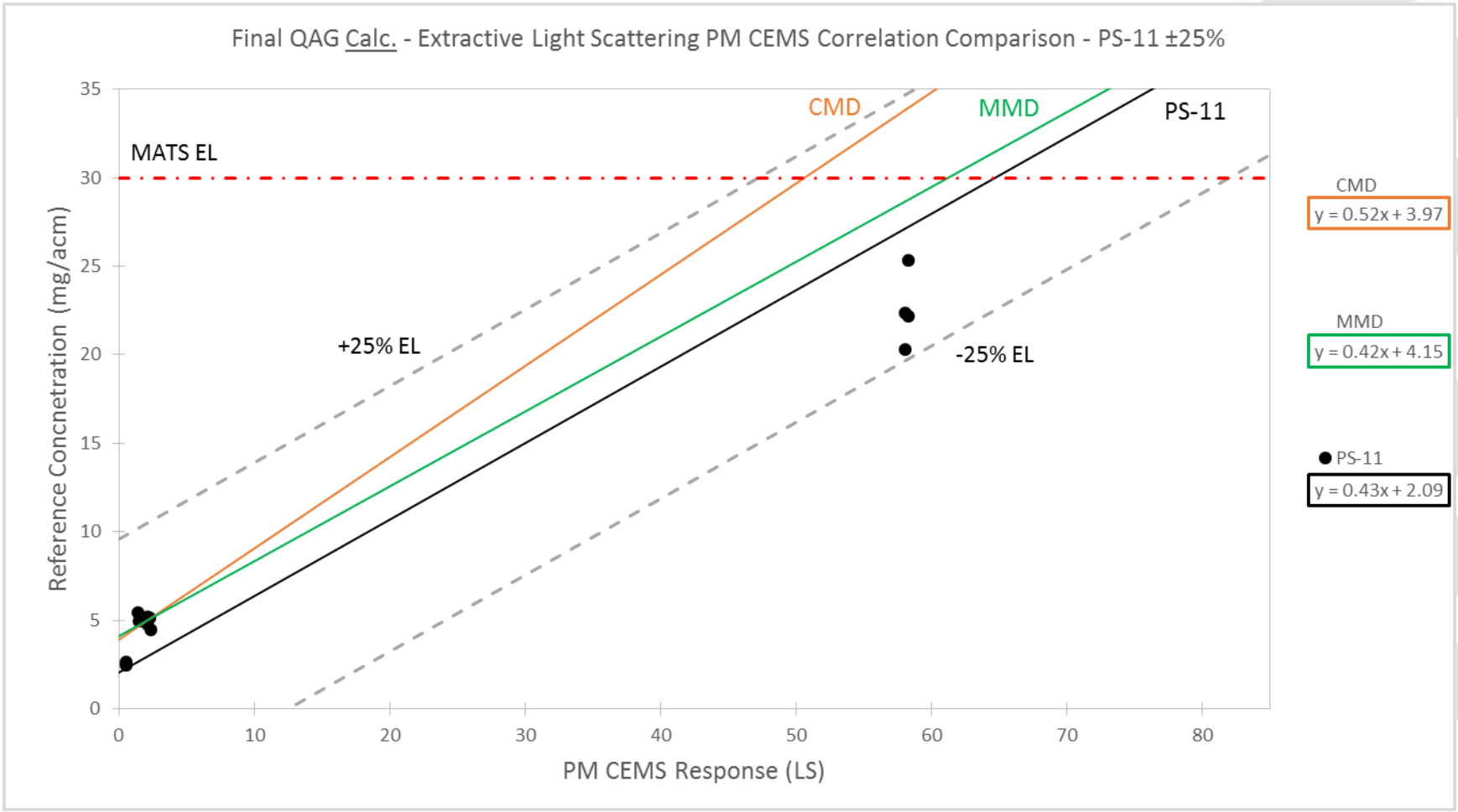
COOPER ENVIRONMENTAL

Position Final PM CEMS Concentration Correlation/Calibration Slope to Pass Through the Average Coordinate from Step 3b by only Changing the y-intercept



COOPER ENVIRONMENTAL

QAG Concentration Correlation/ Calibration Comparison to PS-11



COOPER ENVIRONMENTAL

Conclusions

- If the appropriate application protocol is used, an offline Calibrator like the QAG can be used to calibrate a PM CEMS, giving accurate PM concentrations within a CFPP flue
- Data suggests extractive PM CEMS are more sensitive to mass PSD then count (QAG must match mass PSD)
  - Extractive system deposition
- Further work is needed to define which PSDs need to be used for which PM CEMS operational technology (beta attenuation vs light scattering) and operating systems (in-situ vs extractive)

COOPER
ENVIRONMENTAL

QUESTIONS?
Booth # 12

For further information contact:
Troy Pittenger
troyp@cooperenvironmental.com
503-505-6195